Corona-Solar Wind Energetic Particle Acceleration (C-SWEPA) Modules

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Matthew Gorby

9th CCMC Community Workshop
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University of New Hampshire

Outline

C-SWEPA Goals

Investigator Highlights and Accomplishments

Various Branches of the Project: Comparison w/ Observations

Overview of Deliverables

Partnering with the CCMC

C-SWEPA Goals

Goal 1: Scientifically explore the seed populations and acceleration of energetic particles in the low corona, through interplanetary space, and over broad longitudinal regions.

Goal 2: Couple the energetic particle acceleration model (EPREM, the energetic particle radiation environment model) with MHD models that describe the propagation of coronal mass ejections from the low coronal plasma environment through the interplanetary medium.

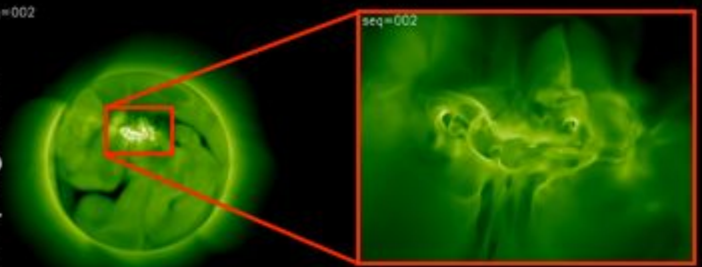
Goal 3: Validate results the coupled EPREM and EMMREM models with observations at distributed observers near 1 AU and out beyond Mars. Validation extends across our understanding of radiation induced hazards from solar energetic particles and galactic cosmic rays at Earth down to atmospheric levels, out into deep space and to Mars and beyond.

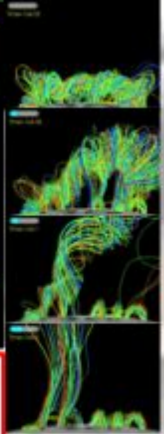
Goal 4: Extend key data sets useful for the project: shock parameters at 1 AU, CME propagation data, and radiation environment data through the inner heliosphere.

Coronal-Solar Wind Energetic Particle Acceleration Modules (C-SWEPA)

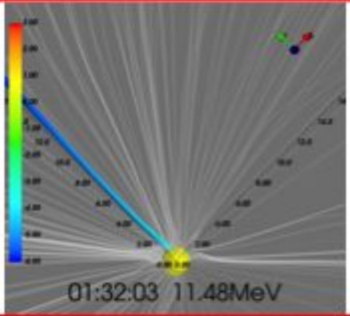
UNH-PSI-SwRI-GSFC/CCMC

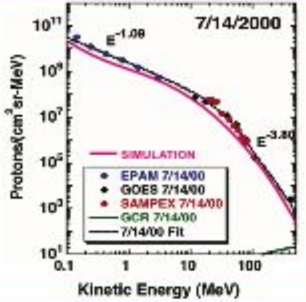
CME Initiation & Propagation



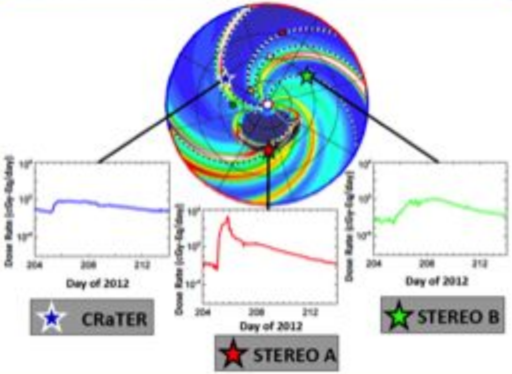


Simulated Solar Energetic Particles





Validation through Observational Comparison

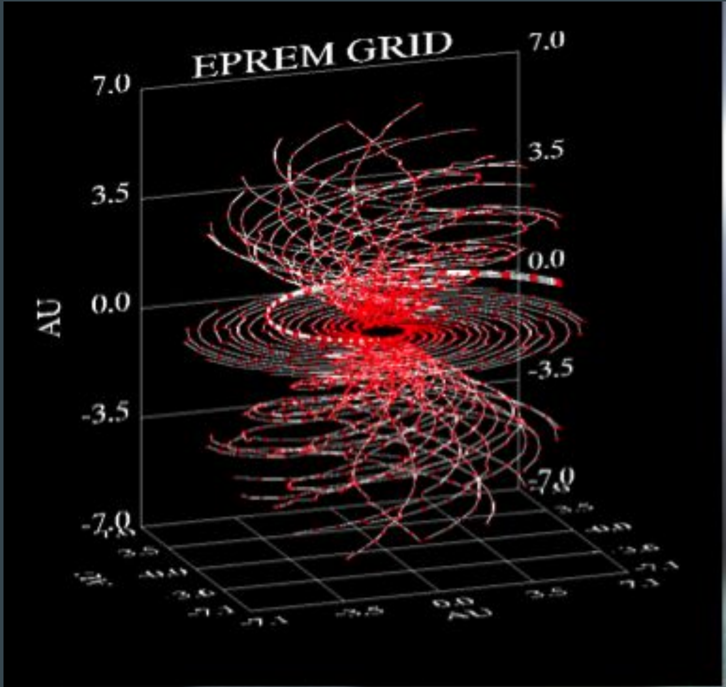


Emerging Community of Researchers and Leaders

- Breakthroughs concerning Energetic particle seed populations
- Discoveries of radiation sources and hazards
- New radiation and analysis simulation tools
- Extensions of Key datasets
- 5 High-end computational deliverables to CCMC
- 45 Refereed Journal Articles
- 7 PhDs since 2012
- 3 PostDocs
- 1 Masters Student

Investigator Highlights

- Matt Gorby (UNH), Jon Linker*, Ron Caplan*, Tibor Török*, Cooper Downs* (*PSI)
  - Fantastic work on development, coordination, coupling
  - Work with PSI and CCMC
- Leila Mays, CCMC
  - Excellent partner at the CCMC
  - Currently leading a C-SWEPA publication
  - Invited talks at AGU, EGU, on coupled modeling
- Colin Joyce
  - Graduated!
  - Authored or Co-authored 14 publications, first-authored 5 publications in diverse areas
- Reka Winslow
  - New PostDoc at UNH
  - Several new discoveries about the evolution of Coronal Mass Ejections through conjunction events from Messenger to ACE, STEREO and LRO
- Junhong Chen
  - Recently received PhD
  - Work on suprathermal ions and PUI acceleration
- Philip Quinn
  - Graduating Soon(™)
  - Leading three papers on pickup ions, suprathermal ions and radiation through the inner heliosphere
- Fatemeh Rahmanifard
  - Studying evolution of the solar cycle, possible development of grand minimum and implications for radiation



Focused Transport in Lagrangian Frame (Kota, 2005)

$$\left(1-\frac{(\vec{u}\cdot e_b)v\mu}{c^2}\right)\frac{df}{dt}+v\mu\frac{\partial f}{\partial z}+\frac{(1-\mu^2)}{2}\left[v\frac{\partial \ln B}{\partial z}-\frac{2}{v}e_b\cdot\frac{d\vec{u}}{dt}+\mu\frac{d\ln(n^2/B^3)}{dt}\right]\frac{\partial f}{\partial \mu}+$$

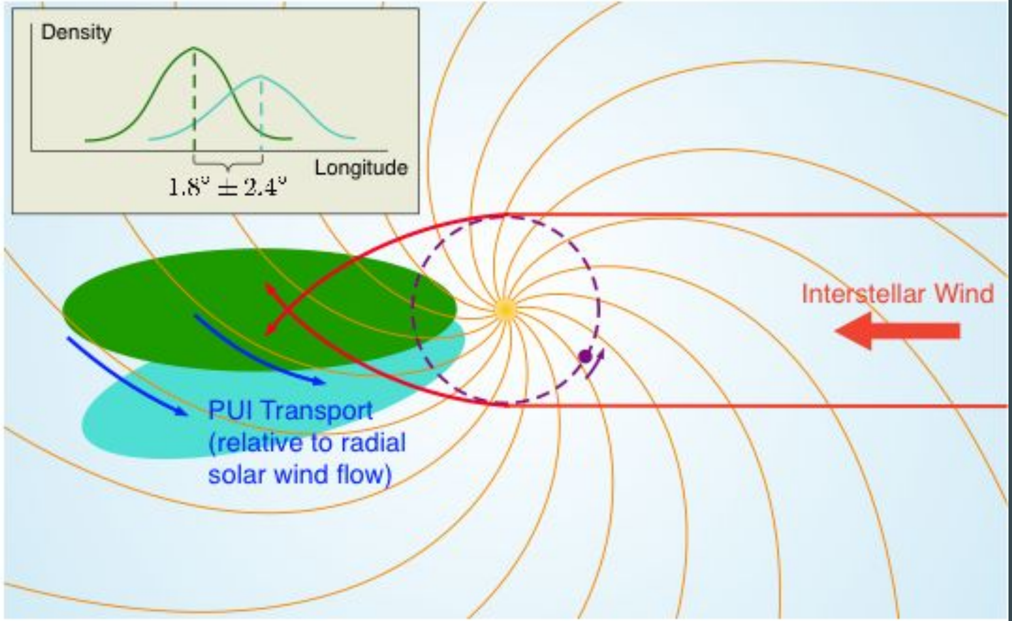
$$\left[-\frac{\mu e_b}{v}\cdot\frac{d\vec{u}}{dt}+\mu^2\frac{d\ln(n/B)}{dt}+\frac{(1-\mu^2)}{2}\frac{d\ln B}{dt}\right]\frac{\partial f}{\partial \ln p}=\frac{\partial}{\partial \mu}\left(\frac{D_{\mu\mu}}{2}\frac{\partial f}{\partial \mu}\right)+S$$

- Cross-field Diffusion
- Drift

Deriving the Scattering Mean Free Path of Helium Pickup Ions

Pickup ion measurements derive a longitudinal inflow direction of the interstellar wind that is consistently higher than neutral measurements.

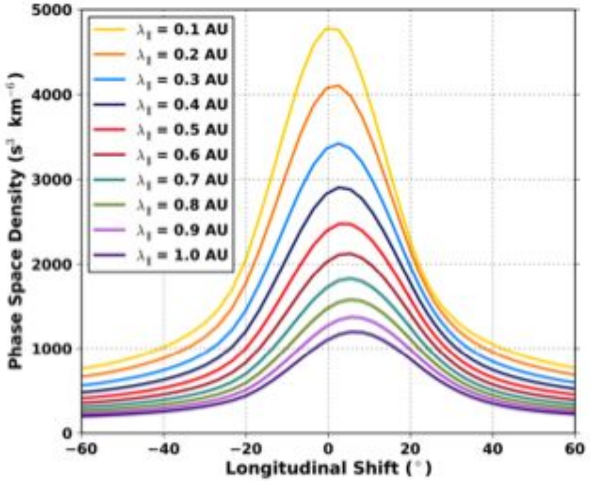
Simulating the transport between neutral focusing cone and pickup focusing cone allows us to derive parameters.



Quinn et al. 2016

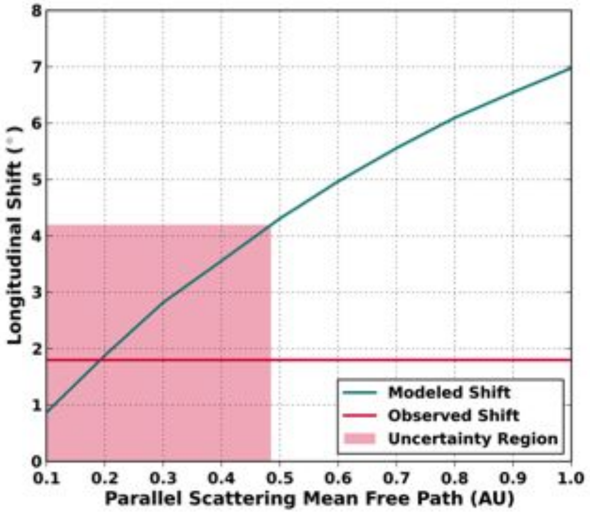
The transport of helium pickup ions is simulated using EPREM for a mean free path range of 0.1 AU to 1 AU.

The longer the mean free path, the more the pickup focusing cone shifts compared to the neutral focusing cone.



The peak longitudes are plotted against mean free path.

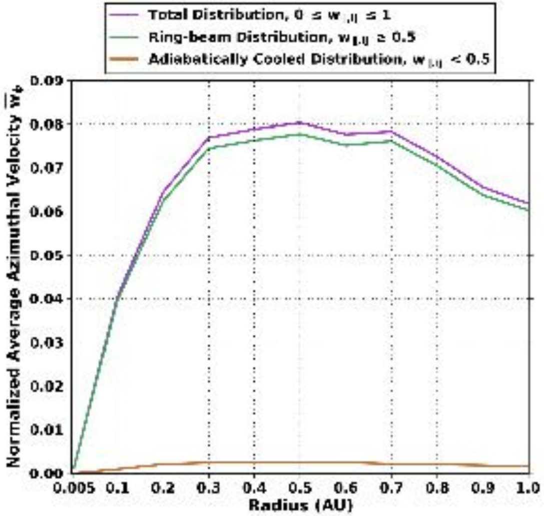
The modeled shift intersects the observed shift at 0.19 AU +0.29(-0.19) AU.



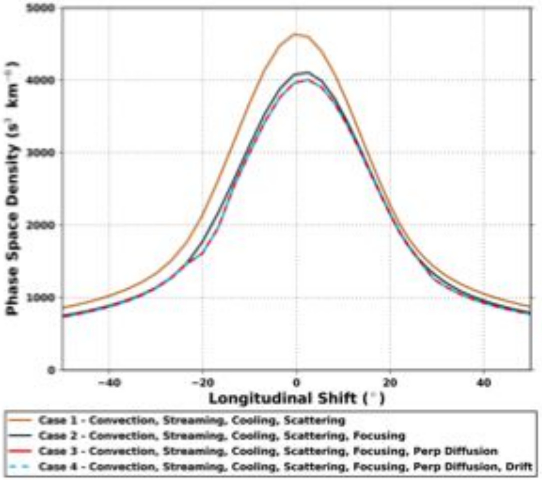
The amount of shift is suggested to be due to an anisotropic velocity distribution.

By calculating the average azimuthal velocity of the pickup ions, we see that the pickup ion distribution reaches ~8% of the solar wind speed inside 1 AU.

Although this velocity is small, it's enough to shift the focusing cone by the 1.8 degree observation difference.

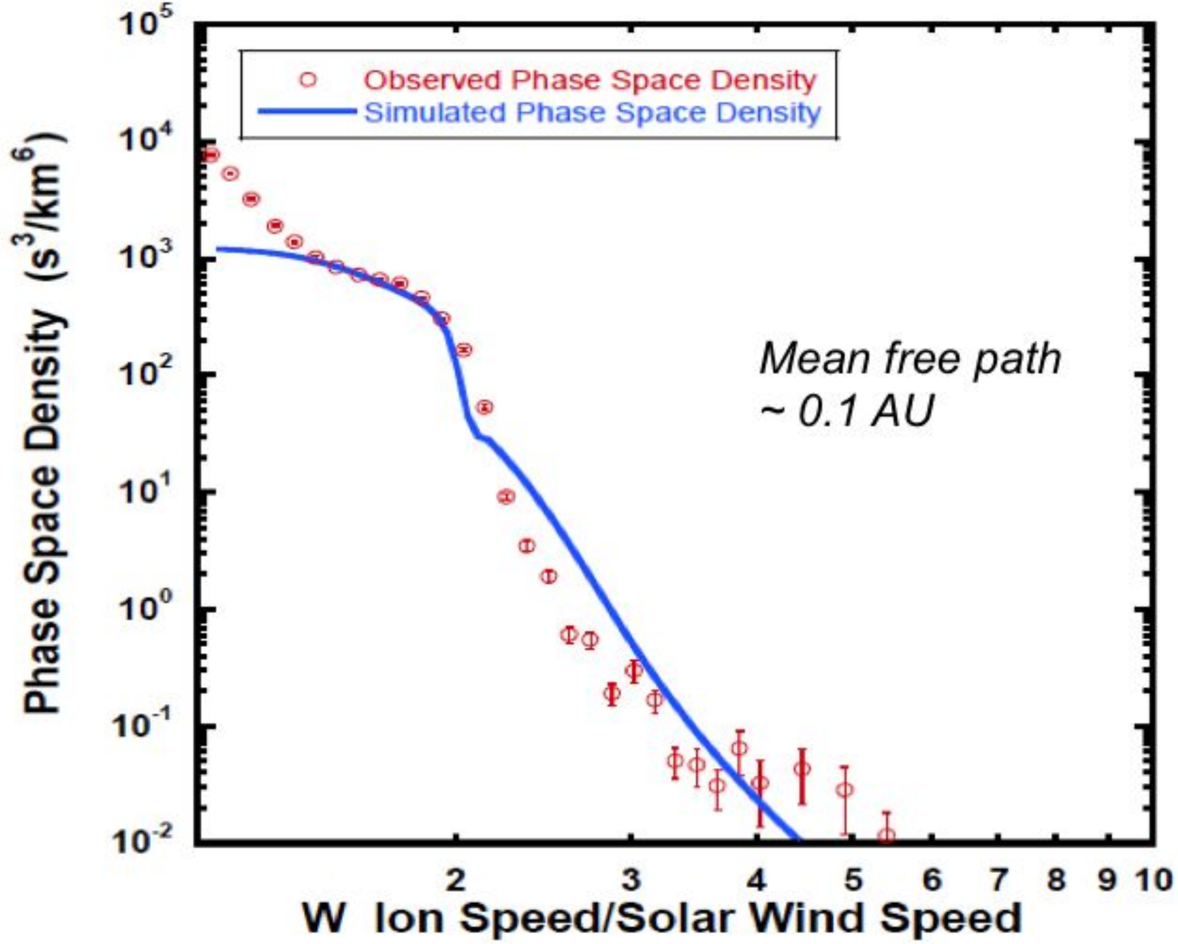


Using EPREM's ability to turn transport effects on or off, EPREM is ran for the 4 cases shown in the figure caption.

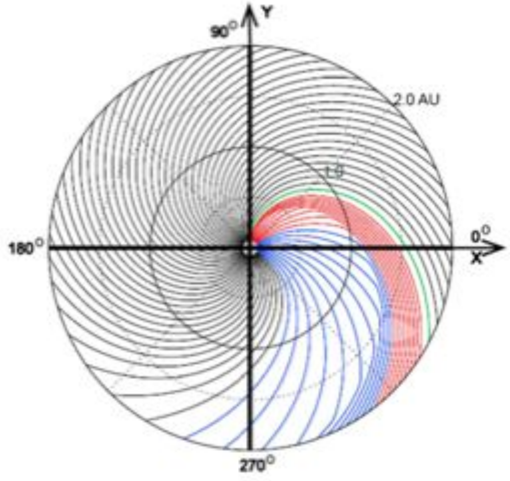


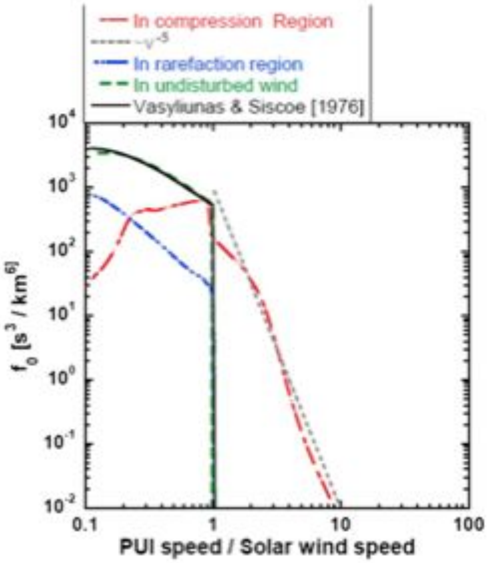
The amount of shift from each transport effect is found by differencing the peak longitude with the previous case.

Pitch-angle scattering	20.00%
Adiabatic focusing	69.43%
Perpendicular diffusion	10.56%
Particle drift	<0.01%



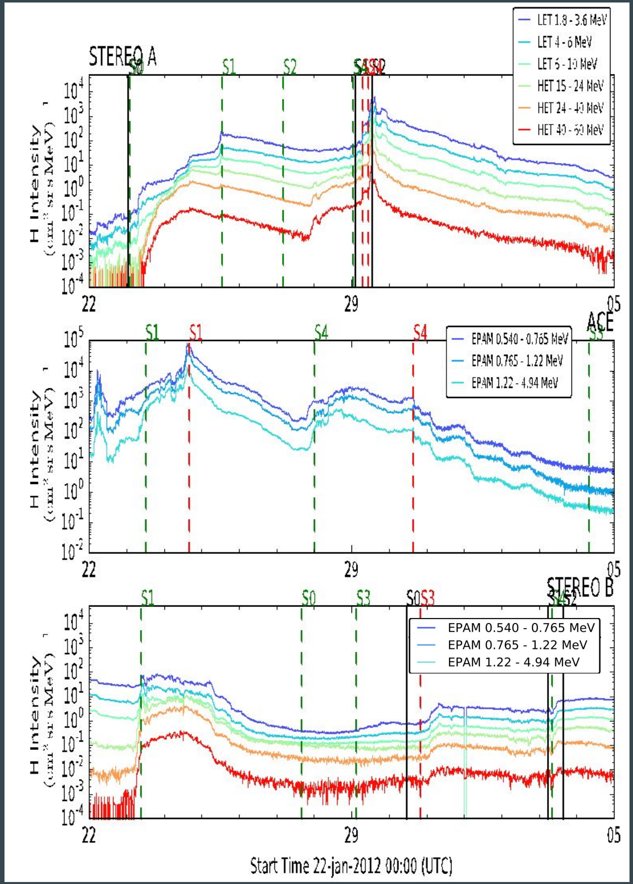
Chen et al., 2015, 2016

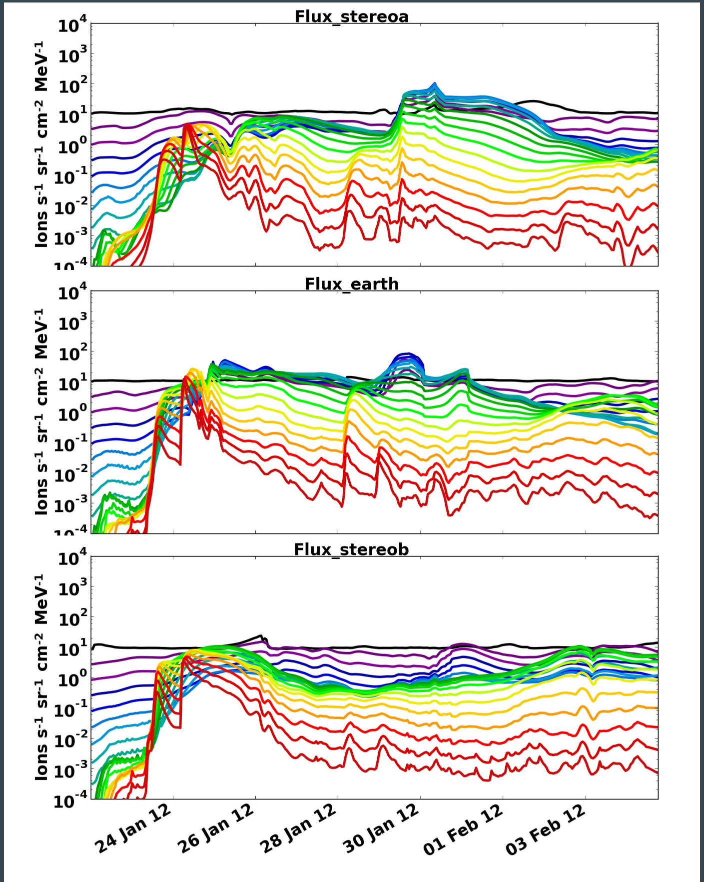


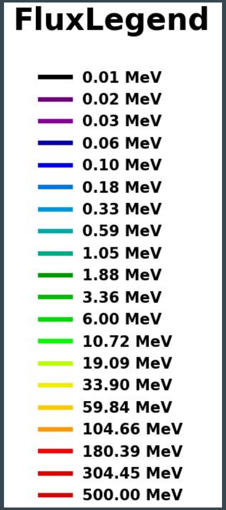


Jan 2012 ENLIL+EPEM results

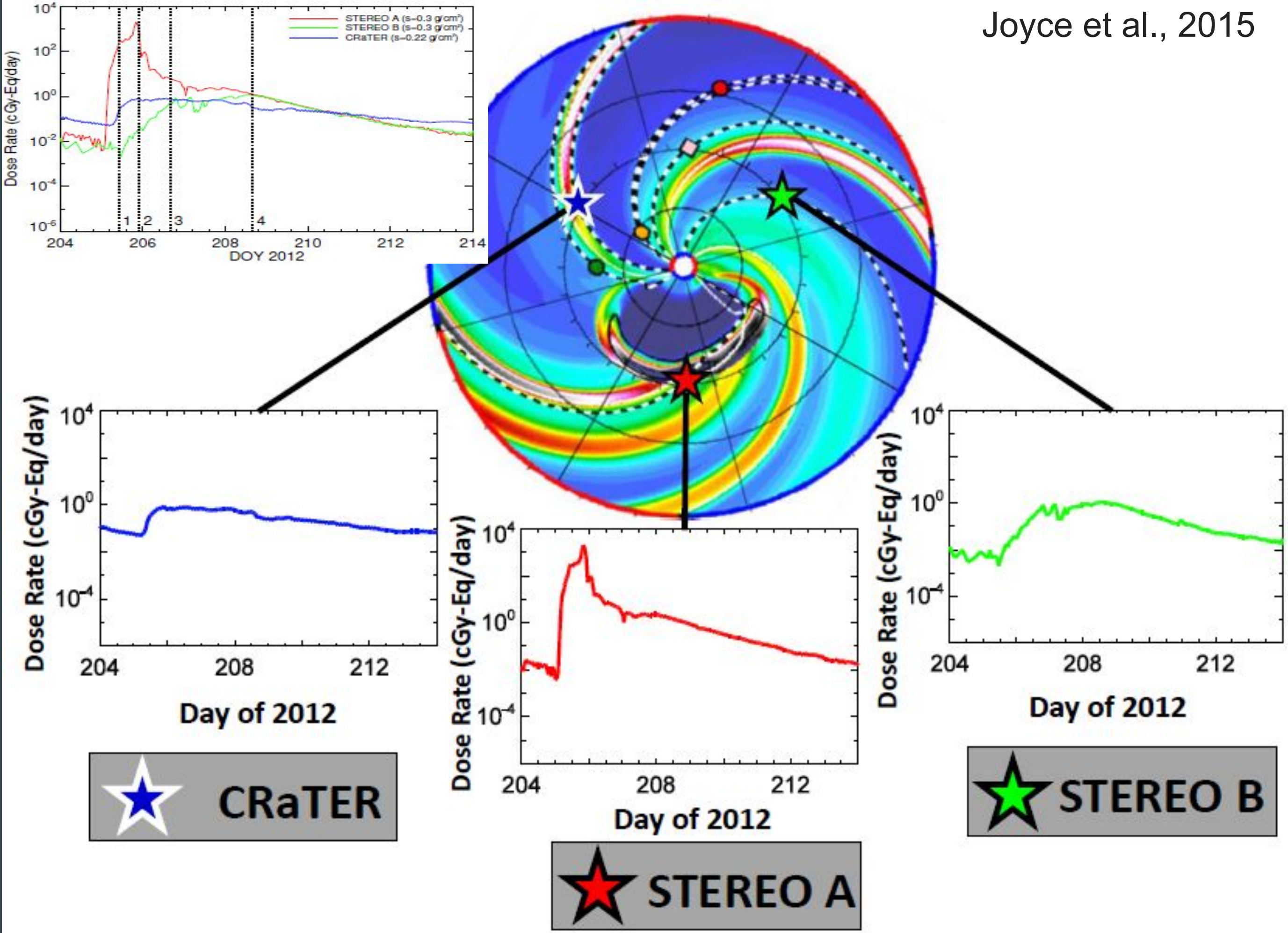
Data plot by Hazel Bain



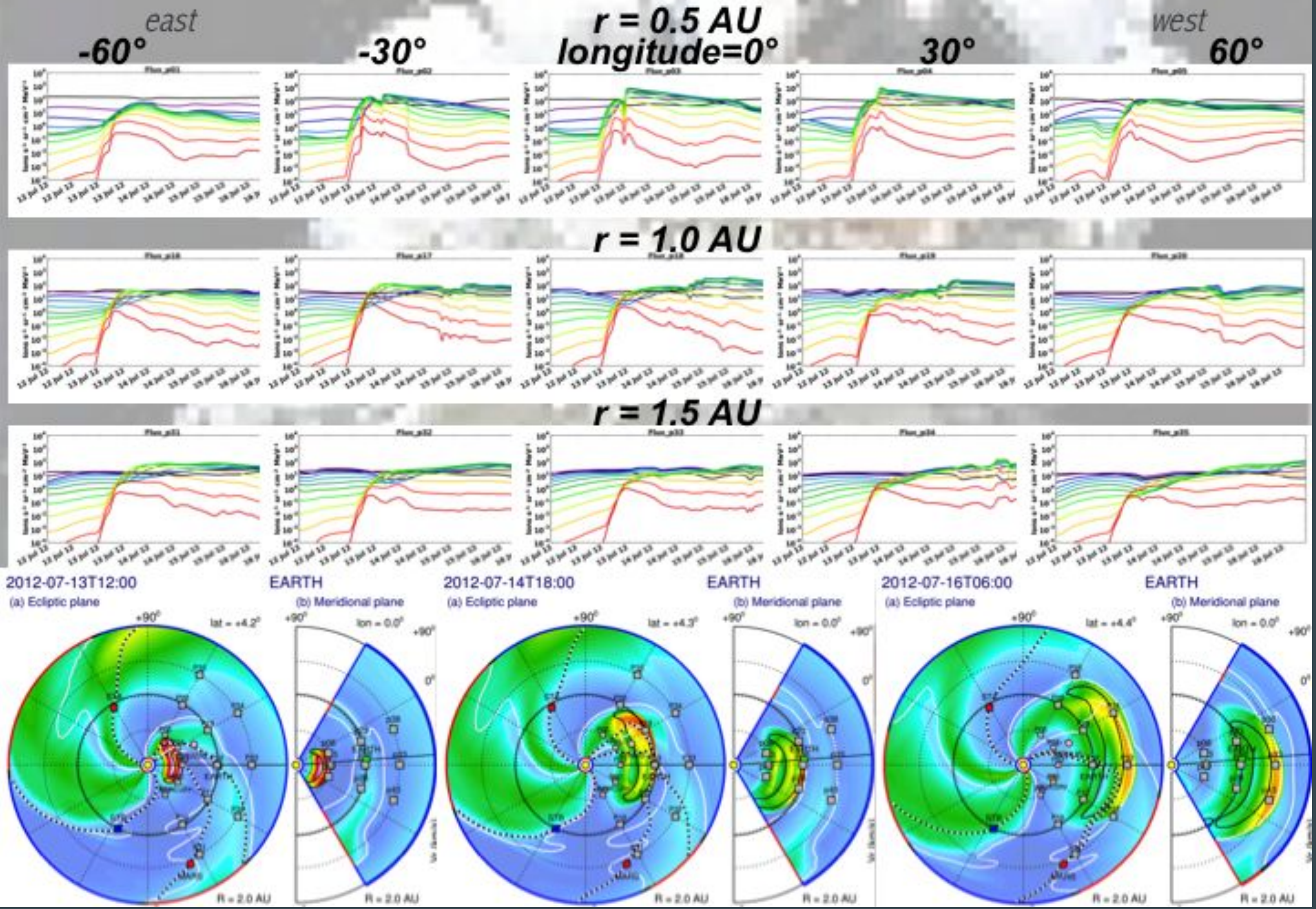




Joyce et al., 2015



EPREM SEP profiles at different observers (latitude=0°)



Overview of Deliverables

- Deliverables Outside the CCMC
  - PREDICCS: Running in real-time radiation environment. http://prediccs.sr.unh.edu
  - EPREM + MAS: Coupled codes running simulations below 20 Rs.

- Deliverables to the CCMC
  - PREDICCS: Installed and running in real-time. https://ccmc.gsfc.nasa.gov/ccmc-swan/prediccs.php
  - EPREM: Installed and working toward runs-on-request.
  - EPREM + Cone: Installed and working toward runs-on-request.
  - EPREM + WSA-Enlil: Installed, simulations are being tested / validated. Preliminary runs results are listed at: http://ccmc.gsfc.nasa.gov/community/LWS/lws_cswepa.php

Partnering with the CCMC

Single point of contact: Leila Mays.

Plenty of communication both directly and through weekly project teleconferences.

Travel to Goddard for model integration was always a pleasure.

Delivery of model and integration was (necessarily?) ill defined.